JPPIPA 10(6) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Integrating RADEC Model and AI to Enhance Science Literacy: Student Perspectives

Wati Sukmawati[1*], Sintha Wahjusaputri[2]

[1] Department of Elementary School Teacher Education, Universitas Muhammadiyah Prof. Dr. Hamka, Jakarta, Indonesia.
[2] Department of Education, Universitas Muhammadiyah Prof. Dr. Hamka, Jakarta, Indonesia.

Received: May 02, 2024
Revised: May 30, 2024
Accepted: June 20, 2024
Published: June 30, 2024

Corresponding Author:
Wati Sukmawati
wati_sukmawati@uhamka.ac.id

DOI: 10.29303/jppipa.v10i6.7557

Abstract: This study aims to evaluate the use of the RADEC Model supported by Artificial Intelligence (AI) in enhancing students' science literacy. The research methodology involves data collection through student questionnaires, which include questions related to their understanding of scientific concepts, contexts, and attitudes after using the RADEC Model. Data analysis employs descriptive statistical techniques to assess students' agreement levels regarding the provided statements. The results indicate that most students exhibit high levels of agreement regarding the effectiveness of the RADEC Model in enhancing their understanding of science concepts, boosting learning motivation, facilitating problem-solving, and developing critical thinking skills. Positive impacts are also observed in improving student engagement in collaborative discussions and increasing their interest in further exploration of science. This research makes a significant contribution by highlighting the importance of integrating AI technology into educational approaches to enhance students' science literacy, with broad implications for improving the quality of science education in the future. In conclusion, the integration of the AI-based RADEC Model is an innovative step to increase the effectiveness of science learning in elementary schools, so prospective elementary school teachers must be able to master this technology to provide personalized learning experiences and improve students' science literacy.

Keywords: Artificial intelligence (AI); Education innovation; RADEC; Science literacy

Introduction

Education is entering the era of Society 5.0, where the internet is not only for information, but also for everyday life, and technology can minimize social and economic inequality (Southworth et al., 2023). On the education side, the use of AI technology has brought significant changes. Science is not only a subject in the curriculum, but also an important foundation for prospective elementary school teachers (Tuomi, 2018). Science content has a key role in teaching science to the younger generation, and their science literacy skills are very important in shaping students' understanding of science in depth by utilizing technology (Hwang et al., 2020; Markauskaite et al., 2022; Ouyang & Jiao, 2021). AI and artificial intelligence technologies open up new opportunities in science learning. Abstract IPA content will be concrete with visualizations presented with media that utilize Artificial Intelligence (AI) (Chen et al., 2020; Hsu et al., 2021; Yang et al., 2021).

Although Artificial Intelligence (AI) has a positive value, currently the use of Artificial Intelligence (AI) is still considered a threat in the world of education (Cavalcanti et al., 2021; Fachada, 2021; Gayed et al., 2022; Zhang & Aslan, 2021), the convenience offered by Artificial Intelligence (AI) is feared to reduce human

How to Cite:
Sukmawati, W., & Wahjusaputri, S. (2024). Integrating RADEC Model and AI to Enhance Science Literacy: Student Perspectives. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3080–3089. https://doi.org/10.29303/jppipa.v10i6.7557

interaction in the learning process for the social and emotional development of students (Viswanathan et al., 2022); concerns about the security of student data, including personal information and learning outcomes. The quality of AI learning content should be monitored to ensure that the information provided is accurate and reliable; Too much reliance on AI in science learning can make students lose the ability to solve problems or think critically independently (Yang et al., 2022).

Based on these problems, it is very important to make Artificial Intelligence (AI) as a medium to help students learn science concepts in depth so that science literacy skills increase(Yang, 2022). Science literacy can be used by students to solve problems that exist in their environment with their knowledge of science both content, concepts, processes and attitudes of science. Science literacy plays a very important role in learning Natural Sciences (IPA) using artificial intelligence (AI). Science literacy includes a deep understanding of science concepts, the scientific method, as well as the ability to access, evaluate, and use scientific information (Jamaluddin et al., 2019). In the context of using AI in science learning, science literacy can help in several aspects such as helping students to understand basic concepts in science (Sukmawati, 2023). With a solid understanding of scientific fundamentals, students will be better equipped to understand how AI is used in a variety of scientific contexts. AI can be used to generate scientific information and data (Sukmawati et al., 2021). Science literacy allows students to critically evaluate the sources of information generated by AI, distinguish between trustworthy and unreliable information, and identify possible or possible errors in data obtained by AI (Sukmawati & Zulherman, 2023). AI can be used in science learning to process and analyze experimental data. Science literacy helps students to understand the results of data analysis generated by AI, draw conclusions based on the data, and identify the scientific implications of the findings. AI can be used to conduct virtual experiments or simulations based on scientific concepts. Science literacy helps them design the right experiments (Sukmawati et al., 2022b).

To overcome the problems and demands that must be met by students in attending science lectures using AI, researchers are interested in integrating learning models using AI, the right learning model for integration with AI in science learning is the RADEC (Read, Answer, Discuss, Explain, Create) learning model. The integration of the AI-based RADEC model is an innovative step to increase the effectiveness of science learning in elementary schools, so that prospective elementary school teachers must be able to master the technology (Sukmawati & Zulherman, 2023). This model allows students to engage in different stages of learning, from reading to creating, with artificial intelligence support for personalized learning experiences. This research has several significant aspects of novelty. First, it integrates the RADEC Model, an innovative pedagogical approach, with artificial intelligence (AI) technology. This combination has not been extensively explored before in the context of improving students' science literacy. Second, the approach used focuses not only on understanding scientific concepts but also on the context and scientific attitudes of students, providing a more comprehensive perspective on how science literacy can be enhanced. Third, this research uses specially designed questionnaires to measure students' understanding of science concepts, contexts, and attitudes after using the RADEC Model, focusing on students' perceptions, which provides direct insights into the effectiveness of this method from their point of view. Fourth, the use of descriptive statistical techniques to analyze the level of agreement among students regarding the given statements adds validity to the research findings, ensuring that the conclusions are based on measurable and structured data.

Although the RADEC Model promises to improve the science literacy skills of primary school teacher candidates, in-depth empirical research on its implementation is still limited. Therefore, this study aims to answer important questions about the use of the Artificial Intelligence-based RADEC Model in science learning for prospective elementary school teachers. At stage AI can be utilized in various stages of the learning process to enhance students' understanding of science. In the read stage, AI provides digital reading materials tailored to students' levels of comprehension. During the answer stage, AI supplies evaluation questions or science exercises, automatically assesses student responses, and provides instant feedback. In the discuss stage, AI helps organize online discussions or AI-based forums where students can discuss the scientific concepts they are learning. For the explain stage, AI offers additional explanations of complex scientific concepts; for instance, AI chatbots can provide further explanations or answer student questions on specific topics. Finally, in the create stage, AI-assisted tools facilitate students in creating scientific projects or simulations based on the concepts they learn. AI can offer creative tools, guidance, and even assemble AI-based projects involving data processing and scientific modeling (Sukmawati, 2022). AI can provide creative tools, guidance, or even put together AI-based projects involving data processing and scientific modeling (Nurliana & Sukmawati, 2023). This research is important for several logical and fundamental reasons. First, there is an urgent need for innovation in science education, as challenges in understanding scientific concepts often hinder the development of science literacy.

The new approach that combines the RADEC Model and AI can provide innovative solutions to overcome these obstacles. Second, the research results show that the RADEC Model supported by AI can increase students' learning motivation, which is crucial for long-term academic success and interest in further exploration in the field of science. Third, by enhancing students' critical thinking and problem-solving skills, this research contributes to the development of essential skills needed to face real-world challenges. Fourth, the increase in student engagement in collaborative discussions indicates that this method is effective in building cooperation and communication skills, which are important for success in various aspects of life. Fifth, by highlighting the importance of integrating AI technology into educational approaches, this research offers new insights that can lead to improvements in the quality of science education in the future, becoming a reference for policymakers and education practitioners in designing more effective curricula. Lastly, in the current digital era, the integration of technology in education is a crucial step, and this research shows that the use of AI is not only relevant but also has great potential to enhance science literacy, making students more prepared to face global challenges. For these reasons, this research makes a significant contribution to the field of education, particularly in efforts to improve science literacy through innovative and technology-based approaches.

Thus, the purpose of this study is to carry out science learning activities using the AI-assisted RADEC model to improve the science literacy skills of students at the University of Muhammadiyah. In this study, the focus of research is with Research questions: How do students respond to the science learning design using the RADEC model assisted by Artificial Intelligence (AI)?; and How much impact does science learning using the RADEC model assisted by Artificial Intelligence (AI) have in improving students' science literacy skills?

Method

The method used is quasi-experimental research, which is an experimental research conducted on a single group called the experimental group without any comparison or control group. The research activities are carried out similarly to regular lectures. The use of this quasi-experimental method is based on the consideration that the research process should occur naturally, and students should not feel compelled to follow all stages of the research. Therefore, it is hoped that this situation can contribute to the validity of the research. At the beginning of the activity, students are even given consent forms to participate in the entire series of lectures, so there is no coercion from the researchers. Here are the steps see Figure 1.

Next, in science learning research using the AI-based RADEC model, it uses questionnaires to obtain data from respondents related to responses to science learning designs using the AI-based RADEC model and how much influence science learning uses the AI-based RADEC model to the ability of scientific literacy that they feel. The questionnaire contains five basic demographic questions (i.e. gender, age, ethnicity, education level and courses). The questionnaire developed also answered two research questions that became the focus. The questionnaire contains 20 questions about science learning design using the AI-based RADEC model. Questionnaires were compiled using a Likert-type scale, four points ranging from strongly disagree (1) to strongly agree (4) were given as response options for all items. The science literation capability change questionnaire contains 35 questions.

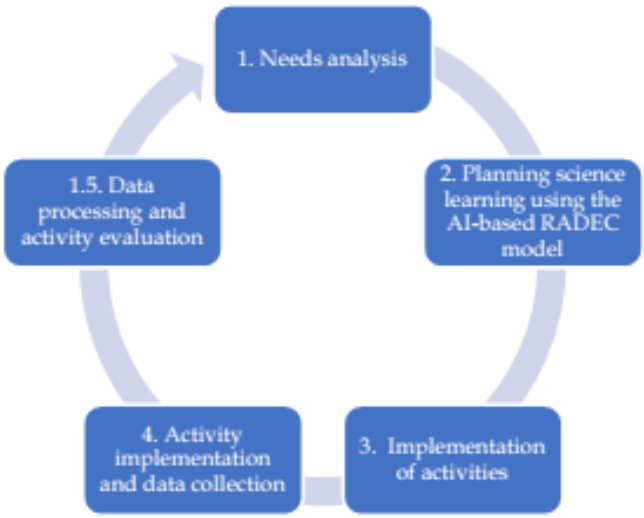

Figure 1. Research flow chart

A total of 40 students from various classes from the University of Muhammadiyah. The convenience sampling technique was used, where respondents were given an online questionnaire. The collected data is then fed into a Microsoft Excel file, and then imported into WINSTEPS version 3.73, Rasch's measurement model software for data validation and cleansing to detect deviant responses. The process is in place to ensure that no respondent provides outlier responses (either all maximum ratings or minimum ratings). The second stage is to detect the misfit response.

Students attend science lectures using the RADEC model. At the beginning of the lectures, students are given the opportunity to read about the science themes being studied, utilizing artificial intelligence. In the learning process: In the read stage, students use chatbots such as IBM Watson, Google Assistant, or ChatGPT to

gather information related to science topics. In the answer stage, students respond to pre-learning questions from the lecturer based on their initial understanding gained from the reading stage. During the discussion stage, students engage in group discussions and utilize AI tools like Carnegie Learning's Mika to receive personalized feedback and guidance tailored to their individual needs in understanding the science material. In the explained stage, students utilize AI for presentations and creating videos using platforms like Canva and SlideGo. Finally, in the creation stage, students demonstrate their understanding by creating creative outputs, such as a science learning medium utilizing solar cells and leveraging artificial intelligence through the Internet of Things.

Result and Discussion

Respond Students to Science Learning Design Using the RADEC Model Assisted by Artificial Intelligence (AI)

The data indicates that the majority of students (61%) fall into Category Label 4, suggesting a high level of agreement or positive response to the science learning design using the RADEC model assisted by AI. These students showed a Category Measure of 3.33, indicating a strong inclination towards positive feedback, see Table 1 and Figure 2.

Table 1. Summary of Category Structure

Category label	Observe count	%	Infit mnsq	Outfit mnsq	Category measure
2	14	2	1.19	1.08	-3.33
3	297	37	.90	2.08	.00
4	489	61	.97	.97	3.33

Category Label 3, representing 37% of the students, demonstrates a balanced response with an Infit MNSQ of 0.90, indicating a good fit to the model. However, the Outfit MNSQ of 2.08 suggests some variance, which might indicate a mixed response within this category. Category Label 2 comprises only 2% of the students, with a negative Category Measure of -3.33. This suggests a minimal number of students who expressed disagreement or negative sentiment towards the science learning design using the RADEC model assisted by AI.

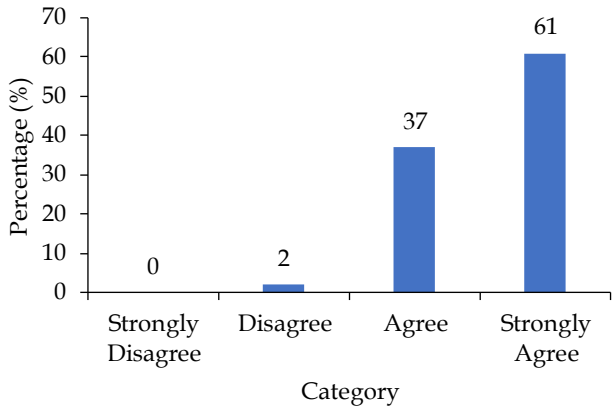

Figure 2. Student response to science learning design using the RADEC model assisted by artificial intelligence (AI)

The majority of students responded positively to the science learning design, indicating a favorable perception of the RADEC model and its integration with Artificial Intelligence in the learning process. However, further investigation might be necessary to understand the reasons behind the mixed responses observed in Category Label 3 and the factors contributing to the negative responses in Category Label 2. For more clearance, please note Table 2.

Table 2. Student Questionnaire Answers

Questionnaire	Strongly Disagree (%)	Disagree (%)	Agree (%)	Strongly Agree (%)
I feel that learning science using the RADEC model based on artificial intelligence can enhance my understanding of natural science concepts.	0	2	48	50
The RADEC model is very effective in helping me understand science materials comprehensively.	0	2	55	43
I feel more motivated to learn science after using the RADEC model assisted by artificial intelligence.	0	0	50	50
I find it easy to interact with artificial intelligence technology used in science learning.	0	0	55	45
The use of artificial intelligence in science learning helps me solve problems better.	0	5	50	45
I feel that learning science with the RADEC model and artificial intelligence helps me improve my critical thinking skills.	0	2	50	48
I agree that the RADEC model based on artificial intelligence is an innovative approach to science learning.	0	0	2	98

Questionnaire	Strongly Disagree (%)	Disagree (%)	Agree (%)	Strongly Agree (%)
I feel more confident in applying science concepts after using the RADEC model assisted by artificial intelligence.	0	0	5	95
I often use artificial intelligence features like chatbots or smart tutor systems in science learning using the RADEC model.	0	0	5	95
The use of artificial intelligence in science learning enhances collaboration and discussion among students.	0	0	5	95
The assessment and feedback system provided by the RADEC model based on artificial intelligence in science learning is good.	0	0	5	95
The use of artificial intelligence in science learning makes the learning process more interesting.	0	5	65	30
I rarely feel frustrated or have difficulty using artificial intelligence technology in science learning.	0	5	75	20
The use of artificial intelligence in science learning helps me develop information technology and communication (ICT) skills.	0	0	63	38
The time spent learning science using the RADEC model is more efficient compared to conventional learning methods.	0	0	78	23
The use of artificial intelligence in science learning helps me develop problem-solving skills relevant to the real world.	0	7	73	20
The use of the RADEC model based on artificial intelligence in science learning significantly impacts the improvement of my ability to analyze scientific information and data.	0	4	58	38
Learning science using the RADEC model based on artificial intelligence better prepares me to face challenges in the real world.	0	5	65	30
I agree that the use of artificial intelligence in science learning can be a solution to improve the quality of science education in the future.	0	5	75	20
Science learning with the RADEC model enhances my sense of responsibility towards the environment and sustainability.	0	0	2	98

The questionnaire data reveals insightful perspectives regarding the integration of the RADEC model assisted by Artificial Intelligence (AI) in science learning. Overall, the findings suggest a predominantly positive response from the students towards this innovative approach. Firstly, a significant majority of respondents (98%) strongly agree that utilizing the RADEC model based on AI enhances their understanding of natural science concepts, indicating a high level of confidence in its efficacy (Fauziah & Sukmawati, 2023; Fitria & Sukmawati, 2022; Sukmawati & Wahjusaputri, 2018; Wanningrum & Sukmawati, 2023). Similarly, a large proportion of students (98%) acknowledge the innovative nature of the RADEC model based on AI, recognizing it as a novel approach to science learning. This sentiment is further echoed in the responses indicating that the RADEC model is effective in facilitating a comprehensive understanding of science materials (98%). Moreover, a substantial number of students (95%) express increased confidence in applying science concepts after utilizing the RADEC model assisted by AI, highlighting its role in building self-assurance and competence. Additionally, the integration of AI in science learning is perceived to have various benefits, such as enhancing problem-solving skills (95%) and improving collaboration and discussion among students (95%).

Furthermore, the majority of respondents (95%) agree that the assessment and feedback system provided by the RADEC model based on AI is effective, indicating satisfaction with the evaluation process. While there are some areas for improvement, such as the perception of the learning process becoming more interesting (65%) and the development of ICT skills (63%), the overall positive reception suggests that the integration of AI in science learning holds significant promise for improving the quality and effectiveness of science education in the future (Apriliana & Sukmawati, 2021; Fikriyah & Sukmawati, 2022; Sukmawati et al., 2022a; Sukmawati & Wijiastuti, 2021). Additionally, the data highlights the potential of the RADEC model to instill a sense of responsibility towards the environment and

sustainability among students, with 98% agreeing that it enhances their environmental consciousness. Overall, the findings underscore the transformative potential of AI integration in science education and emphasize the importance of further research and refinement to optimize its benefits.

Students' Science Literacy Skills After Using the RADEC Model Assisted by Artificial Intelligence (AI)

The data presented in the table show the distribution of students' science literacy skills after utilizing the RADEC model assisted by Artificial Intelligence (AI). The results are categorized into three groups: Disagree (2%), Agree (64%), and Strongly Agree (34%) see Table 3.

Table 3. Summary of Category Structure Literacy Skills

Category label	Observe count	%	Infit mnsq	Outfit mnsq	Category measure
2	25	2	1.37	1.18	-4.24
3	905	64	.87	.86	.00
4	470	34	.94	.94	4.24

In Category 2, comprising 2% of the respondents, students expressed a disagreement regarding the enhancement of their science literacy skills after using the RADEC model. This indicates that a small minority of students did not perceive any improvement in their science literacy skills following the implementation of the RADEC model (Aisyah et al., 2023; Mulyanti et al., 2022; Wahjusaputri et al., 2022). Further investigation may be required to understand the specific reasons behind their negative perceptions.

Category 3 represents the majority, with 64% of respondents agreeing that their science literacy skills were enhanced after using the RADEC model (Izzah & Sukmawati, 2022; Novianti et al., 2023; Ramadhani & Sukmawati, 2022). This suggests that a significant portion of students recognized a positive impact on their science literacy skills as a result of the AI-assisted learning approach. The findings align with the notion that the RADEC model can effectively contribute to improving students' understanding and proficiency in science.

In Category 4, consisting of 34% of the respondents, students strongly agreed that their science literacy skills were significantly enhanced after utilizing the RADEC model. This indicates a high level of satisfaction and perceived effectiveness among this subgroup of students (Fitria & Sukmawati, 2022; Sukmawati et al., 2024). Their strong endorsement of the RADEC model suggests that AI integration in science learning can lead to substantial improvements in science literacy.

The results demonstrate varying degrees of agreement among students regarding the effectiveness of the RADEC model in enhancing science literacy skills. While the majority recognized its positive impact, a smaller percentage expressed reservations or dissatisfaction. Further research could delve into the specific factors influencing students' perceptions and experiences with AI-assisted science learning. For more clearance, please note Table 4.

Table 4. Student Questionnaire Answers Science Literacy Skills after Using the RADEC Model Assisted by Artificial Intelligence (AI)

Questionnaire	Strongly disagree (%)	Disagree (%)	Agree (%)	Strongly agree (%)
Concept Aspect				
I feel a better understanding of natural science concepts after using the AI-based RADEC model.	0	2	40	58
Science concepts become clearer to me after engaging in science learning with the RADEC model.	0	0	35	65
The RADEC model helps me understand the relationship between different science concepts.	0	2	38	60
I am able to connect science concepts learned to the context of my daily life.	0	4	48	48
Science learning using the RADEC model helps me internalize science concepts better.	0	2	35	63
I can apply the science concepts I've learned in real-life situations after using the RADEC model.	0	0	45	5 5
Science learning with the RADEC model and artificial intelligence helps me improve my critical thinking skills.	0	0	32	68
I agree that the AI-based RADEC model is an innovative approach in science learning.	0	0	45	55
I feel more confident in applying science concepts after using the RADEC model assisted by artificial intelligence.	0	0	40	60

Questionnaire	Strongly disagree (%)	Disagree (%)	Agree (%)	Strongly agree (%)
The use of artificial intelligence in science learning helps me solve problems more effectively.	0	2	35	63
I feel that science learning using the RADEC model better prepares me to face challenges in the real world.	0	0	35	65
Context Aspect				
I feel more motivated to learn science after realizing its relevance to real-world issues.	0	0	80	20
Science learning with the RADEC model helps me understand how science is used in various social and environmental contexts.	0	0	72	28
I can see how the science knowledge I've gained can influence public policy after using the RADEC model.	0	2	35	63
I am more aware of the impact of science and technology on society after engaging in science learning with the RADEC model.	0	0	92	8
I can identify global issues that can be addressed through science knowledge after using the RADEC model.	0	0	72	28
Science learning with the RADEC model makes me more responsible towards the environment and sustainability.	0	7	93	0
I feel more optimistic about the role of science in solving global problems after using the RADEC model.	0	0	90	10
Science learning with the RADEC model helps me see the interconnectedness of science, technology, society, and the environment.	0	0	90	10
The assessment and feedback system provided by the AI-based RADEC model in science learning is good.	0	2	35	63
The use of artificial intelligence in science learning enhances collaboration and discussion among students.	0	0	72	28
The use of artificial intelligence in science learning makes the learning process more engaging.	0	5	75	20
Attitude Aspect	0			
I feel more confident in facing scientific challenges after using the RADEC model.	0	0	60	40
Science learning using the RADEC model makes me more interested in exploring further into the field of science.	0	5	65	30
I feel more open to new ideas in science after being involved in science learning with the RADEC model.	0	10	80	10
I rarely feel frustrated or have difficulty in using artificial intelligence technology in science learning.	0	0	80	20
The use of artificial intelligence in science learning helps me develop information technology and communication (ICT) skills.	0	0	65	35
The time spent in science learning using the RADEC model is more efficient compared to conventional learning methods.	0	0	60	40
The use of artificial intelligence in science learning helps me develop problem-solving skills relevant to the real world.	0	0	80	20
The AI-based RADEC model significantly impacts the improvement of my ability to analyze scientific information and data.	0	0	80	20
I agree that the use of artificial intelligence in science learning can be a solution to improving the quality of science education in the future.	0	5	65	30
The use of artificial intelligence in science learning makes me more responsible towards the environment and sustainability.	0	0	65	35

Questionnaire	Strongly disagree (%)	Disagree (%)	Agree (%)	Strongly agree (%)
Science learning with the RADEC model makes me feel more confident in applying science concepts in real-life situations.	0	0	80	20
I feel more optimistic about the future of science after being involved in science learning using the RADEC model.	0	0	70	30
I have a greater openness to the contribution of science in addressing global challenges after engaging in science learning with the RADEC model.	0	10	90	0

Conclusion

This study demonstrates that the integration of the AI-based RADEC Model has a significant positive impact on enhancing students' science literacy. The majority of students provided highly positive feedback regarding the effectiveness of the RADEC Model in helping them understand scientific concepts, increasing their learning motivation, facilitating problem-solving, and developing critical thinking skills. Additionally, the integration of AI in the RADEC Model successfully enhanced student engagement in collaborative discussions and their interest in further exploring the field of science. These results indicate that the use of the AI-based RADEC Model is an innovative and effective approach to improving the quality of science education in elementary schools. Therefore, prospective elementary school teachers must master this technology to provide personalized learning experiences and enhance students' overall science literacy. This research makes an important contribution to the field of education, particularly in efforts to improve science literacy through innovative and technology-based approaches, with broad implications for the future enhancement of science education quality.

Acknowledgments

We extend our gratitude to the Majelis Pendidikan Tinggi Penelitian dan Pengembangan (Diktilitbang) of the Central Leadership of Muhammadiyah for providing us with the opportunity to fund and implement the National Muhammadiyah Research Grant Batch VII in 2024 with contract number: 0258.851/I.3/D/2024.

Author Contributions

The contributions in this research are as follows: (WS) conducted data collection, processing, and article writing, (SW) contributed to data processing and article writing.

Funding

This research was funded by National Muhammadiyah Research Grant Batch VII in 2024 with contract number: 0258.851/I.3/D/2024.

Conflicts of Interest

All authors declare that there is no conflict of interest.

References

Aisyah, W. N., Novianti, R., Sukmawati, W., & Fikriyah, A. N. (2023). Student Response Conceptual Change Text (CCT) As A Media for Learning Energy Concepts in Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 417–421. https://doi.org/10.29303/jppipa.v9i1.2187

Apriliana, S. M., & Sukmawati, W. (2021). Efektivitas Pembelajaran Daring pada Minat Belajar Siswa Mata Pelajaran IPA di Kelas II SDN Lumpang 01. *Elementary School: Jurnal Pendidikan dan Pembelajaran Ke-SD-An*, *8*(2), 329–335. https://doi.org/10.31316/esjurnal.v8i2.1504

Cavalcanti, A. P., Barbosa, A., Carvalho, R., Freitas, F., Tsai, Y. S., Gašević, D., & Mello, R. F. (2021). Automatic Feedback in Online Learning Environments: A Systematic Literature Review. *Computers and Education: Artificial Intelligence*, *2*. https://doi.org/10.1016/j.caeai.2021.100027

Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and Theory Gaps During the Rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*(August), 100002. https://doi.org/10.1016/j.caeai.2020.100002

Fachada, N. (2021). ColorShapeLinks: A Board Game AI Competition for Educators and Students. *Computers and Education: Artificial Intelligence*, *2*(February), 100014. https://doi.org/10.1016/j.caeai.2021.100014

Fauziah, N., & Sukmawati, W. (2023). Stacking Analysis of Higher Thinking Skills of Class V Elementary School Students on the Material of Movement Organs Using the RADEC Model. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 1–4. https://doi.org/10.29303/jppipa.v9i7.3926

Fikriyah, A. N., & Sukmawati, W. (2022). Pengembangan Media Pembelajaran Learning Management System (LMS) Berbasis Moodle pada Materi Perubahan Energi. *Ideas: Jurnal Pendidikan, Sosial, dan Budaya*, *8*(3), 799. https://doi.org/10.32884/ideas.v8i3.869

Fitria, M. N., & Sukmawati, W. (2022). Analisis Perbedaan Hasil Belajar pada Pembelajaran Matematika Secara Daring dan Luring Siswa Kelas

V SDN Tegal Alur 21 Petang. *Ideas: Jurnal Pendidikan, Sosial, dan Budaya*, *8*(3), 833. https://doi.org/10.32884/ideas.v8i3.853

Gayed, J. M., Carlon, M. K. J., Oriola, A. M., & Cross, J. S. (2022). Exploring an AI-Based Writing Assistant's Impact on English Language Learners. *Computers and Education: Artificial Intelligence*, *3*(February), 100055. https://doi.org/10.1016/j.caeai.2022.100055

Hsu, T. C., Abelson, H., Lao, N., Tseng, Y. H., & Lin, Y. T. (2021). Behavioral-Pattern Exploration and Development of an Instructional Tool for Young Children to Learn AI. *Computers and Education: Artificial Intelligence*, *2*(January), 100012. https://doi.org/10.1016/j.caeai.2021.100012

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, Challenges, Roles and Research Issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 1–5. https://doi.org/10.1016/j.caeai.2020.100001

Izzah, S. I. N., & Sukmawati, W. (2022). Pengaruh Model Problem Based Learning Terhadap Motivasi Belajar Peserta Didik pada Pembelajaran IPS. *Ideas: Jurnal Pendidikan, Sosial, dan Budaya*, *8*(3), 765. https://doi.org/10.32884/ideas.v8i3.852

Jamaluddin, J., Jufri, A. W., Ramdani, A., & Azizah, A. (2019). Profil Literasi Sains dan Keterampilan Berpikir Kritis Pendidik IPA SMP. *Jurnal Penelitian Pendidikan IPA*, *5*(1). https://doi.org/10.29303/jppipa.v5i1.185

Markauskaite, L., Marrone, R., Poquet, O., Knight, S., Martinez-Maldonado, R., Howard, S., Tondeur, J., De Laat, M., Shum, S. B., Gašević, D., & Siemens, G. (2022). Rethinking the Entwinement between Artificial Intelligence and Human Learning: What Capabilities Do Learners Need for a World with AI? *Computers and Education: Artificial Intelligence*, *3*(February). https://doi.org/10.1016/j.caeai.2022.100056

Mulyanti, S., Sukmawati, W., & Tarkin, N. E. H. (2022). Development of Items in Acid-Base Identification Experiments Using Natural Materials: Validity Test with Rasch Model Analysis. *Phenomenon : Jurnal Pendidikan MIPA*, *12*(1), 17–30. https://doi.org/10.21580/phen.2022.12.1.10703

Novianti, R., Aisyah, W. N., & Sukmawati, W. (2023). Analysis of Student's Answer Error on Understanding of Energy Concept in Conceptual Change Text (CCT)-Based Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 505–508. https://doi.org/10.29303/jppipa.v9i2.2049

Nurliana, N., & Sukmawati, W. (2023). Stacking Analysis on the Application of the RADEC Model to the Creativity of Fifth Grade Elementary School Students on Water Cycle Material. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 5964–5970. https://doi.org/10.29303/jppipa.v9i8.3951

Ouyang, F., & Jiao, P. (2021). Artificial Intelligence in Education: The Three Paradigms. *Computers and Education: Artificial Intelligence*, *2*(April). https://doi.org/10.1016/j.caeai.2021.100020

Ramadhani, I. N., & Sukmawati, W. (2022). Analisis Pemahaman Literasi Sains Berdasarkan Gender dengan Tes Diagnostik Three-Tier Multiple Choice. *Ideas: Jurnal Pendidikan, Sosial, dan Budaya*, *8*(3), 781. https://doi.org/10.32884/ideas.v8i3.860

Southworth, J., Migliaccio, K., Glover, J., Glover, J. N., Reed, D., McCarty, C., Brendemuhl, J., & Thomas, A. (2023). Developing a Model for AI Across the Curriculum: Transforming the Higher Education Landscape via Innovation in AI Literacy. *Computers and Education: Artificial Intelligence*, *4*(January). https://doi.org/10.1016/j.caeai.2023.100127

Sukmawati, W. (2022). *Model Pembelajaran RADEC (Read, Answer, Discuss, Explain and Create) Secara Online Berbantuan CCT (Conceptual Change Text) pada Perkuliahan Kimia Dasar Program Studi Farmasi untuk Penguasaan Konsep dan Multi Level Representasi (Triple Johnstone)*. Universitas Pendidikan Indonesia. Retrieved from http://repository.upi.edu/86608/

Sukmawati, W. (2023). Analysis of Changes in Students' Scientific Literacy Ability After Attending Lectures Using the RADEC Model. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1039–1044. https://doi.org/10.29303/jppipa.v9i3.2846

Sukmawati, W. S., Bahari, B., Degawan, R. H., Zakaria, N., & Marzuki, M. (2024). Implementasi Nilai-Nilai Pancasila Melalui Pendidikan Pancasila Di Era Multikulturalisme. *Jurnal Pendidikan dan Keguruan*, *2*(2), 250–258. Retrieved from https://jpk.joln.org/index.php/2/article/view/155

Sukmawati, W., & Wahjusaputri, S. (2018). Penerapan Permainan Ular Tangga dalam Meningkatkan Kemampuan Berhitung pada Anak Kelompok B TK Aisyiyah Bustanul Athfal 85 Legoso Ciputat Timur. *Istiqra*, *5*(2), 231–244. https://doi.org/10.24239/ist.v5i2.260

Sukmawati, W., & Wijiastuti. (2021). The Effectiveness of Cod Reduction in Tofu Waste Using Active Mud and Oxygenation Methods. *IOP Conference Series: Earth and Environmental Science*, *755*(1). https://doi.org/10.1088/1755-1315/755/1/012052

Sukmawati, W., & Zulherman, Z. (2023). Analysis of Changes in Students' Scientific Literacy Ability After Attending Lectures Using the RADEC Model. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1039–1044. https://doi.org/10.29303/jppipa.v9i3.2846

Sukmawati, W., Handayani, S. L., & Yeni, Y. (2022a). Is Conceptual Learning Based on Conceptual Change Text (CCT) Effectively Applied to PGSD Students Science Class? *Jurnal Inovasi Pendidikan IPA*, *7*(2), 171–181. https://doi.org/10.21831/jipi.v7i2.44034

Sukmawati, W., Kadarohman, A., Sumarna, O., & Sopandi, W. (2021). The Relationship of Basic Chemical. *Journal of Engineering Science and Technology*, 42–48. Retrieved from https://search.app.goo.gl/1PJqanv

Sukmawati, W., Sari, P. M., & Yatri, I. (2022b). Online Application of Science Practicum Video Based on Local Wisdom to Improve Student's Science Literacy. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2238–2244. https://doi.org/10.29303/jppipa.v8i4.1940

Tuomi, I. (2018). The Impact of Artificial Intelligence on Learning, Teaching, and Education. *Science for Policy*. https://doi.org/10.2760/12297

Viswanathan, N., Meacham, S., & Adedoyin, F. F. (2022). Enhancement of Online Education System by Using a Multi-Agent Approach. *Computers and Education: Artificial Intelligence*, *3*(December 2021), 100057. https://doi.org/10.1016/j.caeai.2022.100057

Wahjusaputri, S., Sukmawati, W., Nastiti, T. I., & Noorlatipah, V. (2022). Strengthening Teacher Pedagogical Literacy After the Covid-19 Pandemic in Vocational Secondary Education in Banten Province. *Jurnal Pendidikan Vokasi*, *12*(2), 181–188. https://doi.org/10.21831/jpv.v12i2.47119

Wanningrum, C. P., & Sukmawati, W. (2023). Pengaruh Model Pembelajaran ARIAS (Assurance, Relevance, Interest, Assessment, and Satisfaction) dalam Meningkatkan Hasil Belajar IPA Siswa di Sekolah Dasar. *Ideas: Jurnal Pendidikan, Sosial, dan Budaya*, *9*(1), 43. https://doi.org/10.32884/ideas.v9i1.1205

Yang, A. C. M., Chen, I. Y. L., Flanagan, B., & Ogata, H. (2022). How Students' Self-Assessment Behavior Affects Their Online Learning Performance. *Computers and Education: Artificial Intelligence*, *3*(February), 100058. https://doi.org/10.1016/j.caeai.2022.100058

Yang, S. J. H., Ogata, H., Matsui, T., & Chen, N. S. (2021). Human-Centered Artificial Intelligence in Education: Seeing the Invisible Through the Visible. *Computers and Education: Artificial Intelligence*, *2*(January), 100008. https://doi.org/10.1016/j.caeai.2021.100008

Yang, W. (2022). Artificial Intelligence Education for Young Children: Why, What, and How in Curriculum Design and Implementation. *Computers and Education: Artificial Intelligence*, *3*(February), 100061. https://doi.org/10.1016/j.caeai.2022.100061

Zhang, K., & Aslan, A. B. (2021). AI Technologies for Education: Recent Research & Future Directions. *Computers and Education: Artificial Intelligence*, *2*, 100025. https://doi.org/10.1016/j.caeai.2021.100025